Comparison of Structure and Segregation in Alloys Directionally Solidified in Terrestrial and Microgravity Environments

D.R. Poirier, Principal Investigator Department of Materials Science and Engineering University of Arizona Tucson, AZ 85721 Phone: (520) 621-6072

Phone: (520) 621-6072 Fax: (520) 621-8059

E-mail: poirierd@u.arizona.edu

S.N. Tewari, Co-Investigator Chemical Engineering Department Cleveland State University

J.C. Heinrich, Co-Investigator Department of Aerospace and Mechanical Engineering University of Arizona

Abstract

The primary purpose of the research is to compare the structure and segregation in binary metallic alloys that are directionally solidified in terrestrial and low gravity environments. The grant was awarded to define growth conditions of directional solidification experiments of a dendritic alloy in microgravity.

Models of dendritic solidification that are used to predict the undercooling during growth of alloys rely on the assumption of diffusional transports of both heat and solute. Important features of the models are the prediction of primary dendritic spacings and the dendrite tip radii. However, in terrestrially solidified alloys the thermosolutal convection of liquid in, from, or close to the solid plus liquid region masks the diffusional processes at the dendrite tips and can cause extensive macrosegregation in directionally solidified samples. Availability of microgravity provides an opportunity to obtain experimental data where thermosolutal convection is negligible. In this grant, growth conditions for such microgravity experiments have been defined by combining mathematical modeling and simulation with the results of terrestrial experiments. Thermosolutal convection is obviously reduced in microgravity, but shrinkage-induced convection and "g-jitter" must be considered.

Based on our research, it is clear that thermosolutal convection strongly affects diffusional transport during solidification and can lead to macrosegregates known as freckles. In terrestrial experiments, therefore, diffusive and convective phenomena occur simultaneously, which complicate the study of dendritic growth. The opportunity to carry out experiments in microgravity would enable us to gain scientific data on dendritic microstructures that would be beneficial in materials processing and would provide benchmark data of dendritic microstructures grown without thermosolutal convection. Using space-grown samples of hypoeutectic Pb-Sb alloys, we will characterize dendrite arm spacings, volume fraction of interdendritic liquid, and both macrosegregation and microsegregation, and compare the results to the structures and segregation in terrestrially grown samples of the same alloy.

The design of the microgravity experiments will also be guided by our computer simulations, which show the effect of g-jitter during solidification in long-duration microgravity experiments. The simulations show that when the g-jitter is applied perpendicular to the growth direction of the

directionally solidified alloy, the resulting convection is sufficient to distort the mushy zone and introduce macrosegregation. Thus experiments in microgravity will require that the furnace must be vibration-isolated within the spacecraft or the Space Station.